

# **Juvenile Chinook Salmon and Adult Delta Smelt Salvage Efficiency at the Tracy Fish Collection Facility During VAMP: Effects of Primary Bypass Ratio on the Whole Facility Efficiency**

## **Principal Investigators**

### **Brent Bridges**

*Fish Biologist  
Tracy Fish Collection Facility  
Bureau of Reclamation  
Tracy, CA 94514  
BBridges@usbr.gov*

### **Zachary Sutphin**

*Fisheries Biologist  
Fisheries and Wildlife Resources Group  
Bureau of Reclamation  
Denver, CO 80225  
ZSutphin@usbr.gov*

## **Study Summary**

California exports approximately 7.3 billion m<sup>3</sup> of water annually from the Sacramento/San Joaquin River Delta (Delta) to central and southern California for agriculture, municipal, and industrial needs. The majority of water is diverted by two pumping facilities in the south Delta: Jones Pumping Plant (JPP) owned by the federal government's Bureau of Reclamation (Reclamation) and Harvey O. Banks Delta Pumping Plant (BPP) owned by the California Department of Water Resources. Both sites are equipped with fish salvage facilities upstream of the pumping plants to reduce the number of fish entrained through the pumps. The fish facilities were designed to capture juvenile Chinook salmon and striped bass (USBR 1956).

The federal Tracy Fish Collection Facility (TFCF) and state Skinner Delta Fish Protective Facility (SDFPF) use a behavioral louver-bypass system to guide fish out of the canal and into collection tanks, where they are held until transported to the northern Delta. Louver system efficiency is strongly dependent on the water velocity in the primary and secondary channels (Bates *et al.* 1960, DWR 1967). In addition, achieving an appropriate bypass ratio (BR; >1.0), defined as the ratio of the water velocity entering the bypass opening to the average channel velocity upstream of the louvers, is reported to be critical in promoting fish to enter a bypass (Bates *et al.* 1960, DWR 1967).

Primary channel velocity is reduced at specific times of the year to save Chinook salmon and delta smelt by reducing exports at the JPP. A reduction in primary channel velocity greatly influences the primary bypass ratio and velocities in the secondary channel. The main goal of this study is to assess how the primary and secondary channel BR influences salvage efficiency of juvenile Chinook salmon and adult delta smelt during low primary channel velocities.

This is a multi-year study. In the first year we focused on salmon and completed approximately 80% of the proposed work. We found that the new holding tank buckets were nearly 100% efficient at retaining salmon, secondary velocity drastically influences travel time, and primary bypass ratios much greater than the standard 1.6 provide better salvage efficiency. In the second year of the study the trashrack in front of the facility was removed, the primary flowmeter was damaged, and the holding tank flowmeters were not accurate; consequently, little data were collected. Continuation of this study is proposed for winter of 2010.

### **Problem Statement**

Operation of the TFCF has historically set the primary bypass ratio to 1.6 during VAMP and allowed the secondary channel velocity to drop below criteria. This has the potential to affect salvage efficiency for the TFCF. Data collected from this project will provide critical information for establishing new BR criteria for the TFCF.

### **Goals and Hypotheses**

#### *Goals:*

1. Measure collection efficiency of new bucket in holding tanks.
2. Determine if the historical operating criteria for the TFCF provides peak salvage efficiency for delta smelt adults and juvenile Chinook salmon.
3. Develop a conceptual model for how bypass ratio in the primary channel influences whole facility efficiency for the five operating scenarios at the JPP.

#### *Hypotheses:*

1. There is a significant positive relationship between secondary bypass ratio and secondary salvage efficiency when the bypass ratio is between 0–1, and 1–4.
2. There is a significant positive relationship between the primary bypass ratio and primary louver efficiency across the range of bypass ratios of 1–6.
3. There is a significant difference in whole facility efficiency between two operating scenarios: Setting the primary bypass ratio to 1.6 and allow the secondary velocity to vary vs. setting the secondary velocity to criteria and allow the primary bypass ratio to vary.

### **Methods/Approach**

#### *Efficiency Experiments:*

Field experiments will be completed during the months of March–June and the study should be completed by December 2012. The trials will be completed when the JPP is operating with 1–3 pumps. During periods of least pumping (*i.e.* 1 JPP), the TFCF primary channel average water velocity is approximately 0–0.3 m/s and our target velocity for testing is >0.15 m/s. Primary channel velocities slower than this cause extreme delays in fish passage; therefore, trials will be completed during incoming tides.

Adult delta smelt (70–100 mm FL) will be attained from the University of California, Davis' Fish Culture and Conservation Lab (FCCL) and juvenile hatchery Chinook salmon (70–110 mm FL) will come from one of the local hatcheries (Mokelumne, Nimbus, Orville, or Coleman). For all experiments, fish will be tagged in the fins (dorsal, anal, or caudal) with the NewWest Technology Photonic Marking Solution (Sutphin and Bridges 2008). All fish will be held in 757-L, black, 1.2-m-diameter polyethylene tanks receiving cleaned (ozonated) Delta water at 10 L/min and within  $\pm 1^{\circ}\text{C}$  of ambient Delta temperature. Each tank will be gently aerated with a small air stone (3.5 cm  $\times$  3.5 cm  $\times$  7 cm) to keep oxygen levels above 7 ppm, and tanks will be covered with shade cloth to keep birds out. Chinook salmon will be fed a mix of 1.5-mm steelhead pellet (Silvercup, Murray, Utah) and 0.6–0.8 mm EPAC ALFA Diet (INVE Aquaculture, Salt Lake City, Utah), and delta smelt will be fed exclusively the EPAC ALFA Diet at 2% body weight per day. Both species will be handled with fine mesh dip nets and transported and released into the experiments with black, 20-L buckets. Buckets are lowered by rope and tipped over at water surface level so that released fish are gently placed into position for all tests. Each day that a trial is completed in the secondary channel the louvers will be cleaned and the predators removed.

*This study will consist of four experiments.*

#### *Experiment 1*

The 10-minute (min) count bucket has been recently modified and it is not known how efficient this device is when collecting fish from the holding tanks. Before it is used for these tests it will be tested to verify it does not leak fish. Test fish (Chinook salmon and delta smelt) will be released directly into holding tanks 2 and 4 before experiments begin to verify the holding tanks and bucket do not leak for small fusiform body shaped fish (60–100 mm FL). Four releases per tank will be completed with 25 fish released per injection. The tanks will collect water for 10 min and then be drained to collect fish. If the mean recovery efficiency is less than 95% then the bucket must be modified to prevent leaking and retested.

#### *Experiment 2*

The second experiment will look at secondary bypass ratio's influence on secondary louver efficiency at three velocities (0.3, 0.6, 0.9 m/s) during daylight hours. This range of velocity covers normal operating velocities. The purpose of this experiment is to see if secondary bypass ratio can be used to predict louver efficiency above bypass ratios of 1.0 at each channel velocity. If there is no significant relationship, then the bypass ratio in experiment 3 will be specified to be between 1.2–1.6 (the operating standard). If there is a significant positive relationship then the bypass ratio will be mandated to be as high as possible.

The secondary channel and holding tanks will be stabilized ( $\pm 0.05$  m/s) at the target velocity and bypass ratio prior to each trial. Hydraulic conditions will be documented at the start of each test. Twenty fish will be released at the head of the secondary channel and the number of fish captured in the holding tank and sieve net will be counted after 20 min. Prior experience with pilot tests have shown trials only need to be 20 min long because >90% of the fish that participate in a trial do so within 20 min at

the standard salmonid velocity criteria. At the slower velocities less than 90% of the fish will participate in each 20-min trial and this is likely to cause greater error in our efficiency estimates. Releasing more than 20 fish at a time would help compensate for fewer fish participating in the experiment; however, we wanted to keep the group of fish entering the test as similar in size as possible to those naturally entering the secondary and we do not want to introduce schooling effects.

After the conclusion of each trial all VC pumps will be turned on for 2 min to wash remaining test fish out of the secondary channel to prevent interference with the subsequent trials and then the next test will commence. One target velocity will be chosen for testing each day and the bypass ratio to test for each trial will be randomized. Thirty trials will be completed at each velocity to generate a regression showing secondary louver efficiency as a function of secondary bypass ratio. The bypass ratios chosen to test for each trial will be randomized and will fall within the range of 0.1–4.0. Specific bypass ratios will not be tested as the facility does not operate by holding the primary or secondary bypass ratio constant. Holding the bypass ratio at a constant condition (*e.g.* 1.2, 1.4, 1.6) is not practical for operating the TFCF as tidal influences quickly change the BR and require constant adjustment (every 15 min) by the operators.

Quality control holding tank fish will be inserted in every holding tank sample (10 fish/tank) to determine if the holding tank bucket was sealed and seated properly. In the past, the bucket's center drain valve has been stuck in the open position and we lost our sample without our knowledge. In addition, the buckets lip does not always seat properly within the drain mount and fish can slide under the lip of the bucket. To prevent these problems from interfering with test results, we will use the recovery of injected controls to judge if the sample has been compromised. If we do not collect at least 8 of the 10 fish injected then the sample must be discarded. Based on previous experience it is impossible to recover 100% of these control fish on a reliable basis as individual fish can be wedged into corners along the screen or piping along the walls of the tank.

### *Experiment 3*

The third experiment will consist of completing whole facility efficiency trials during VAMP, or when pumping is reduced to 1–3 pumps at the JPP, for Chinook salmon and delta smelt across the full range of secondary velocities. These data will be used to generate regression equations for predicting facility efficiencies based on primary bypass entrance velocity, primary channel BR, and secondary velocity during VAMP. Based on the work by Sutphin and Bridges (2008) we are anticipating there is a threshold velocity value that must be reached at the primary bypass entrance before fish will descend inside the bypass and travel towards the secondary channel. This threshold velocity may be comparable to the burst or prolonged swimming speed for each species and should be clearly visible when plotting the trends.

For each day of testing, six trials will be completed during the day and they will evenly cover the entire range of possible primary BRs that are >1. Secondary channel BR will be set according to the data in experiment 2. All six trials will be run during the incoming tide so that the primary channel velocity is nearly constant for each day of testing. Each trial will be monitored for 30 min by checking holding tank and sieve net samples. Previous experience with testing these two species has shown that >50% of the fish participating in these types of experiments come in within the first 30 min when

operating conditions are favorable. One hundred fish will be divided into four groups (25) and inserted at the head of each louver bay. Forty fish will be inserted at the head of the secondary channel.

The sample size for the primary channel injections was selected for two reasons. First, during normal salvage operations we typically collect 1–15 salmon in a 10-min count every 2 h. This means 12–180 fish typically end up in the holding tank every 2 h. In the past, the salmon louver efficiency has been approximately 60% and this means that for every 2 h of facility operation 20–300 fish enter through the trashrack (Karp *et al.* 1995). Therefore, the release group size selected for these tests is similar to the number of fish naturally entering the facility and enough fish are recovered in the holding tanks to still make a comparison between treatments.

#### *Experiment 4*

The forth experiment will investigate operating the facility under two different scenarios (back-to-back paired trials) each for 80 min to determine if whole facility efficiencies are equal. Method one is to set the primary bypass ratio at 1.6 and allow the secondary channel velocity to drop below criteria (3.0–3.5 ft/s, 0.9–1.1 m/s). Method two is to set the secondary velocity at 3.0 ft/s (0.9 m/s) and allow the primary BR to go above the traditional criteria (1.6). In each method of operation, the secondary bypass ratio will be kept above the criteria established in the first experiment. The goal of this test is to be able to detect at least a 30% difference in whole facility efficiency between the methods. Such a large difference in efficiency is expected based on previous work (Sutphin and Bridges 2008); consequently, only 10 paired trials will be completed. This test will only be completed if no clear trend in whole facility efficiency vs. bypass entrance velocity is identified from experiment 3.

One-hundred-forty fish will be used for each trial. One-hundred fish will be divided into four groups (25) and inserted at the head of each louver bay. Forty fish will be inserted at the head of the secondary channel.

#### *Fish Source, Tagging and Care*

Delta smelt will be obtained from the Fish Conservation and Culture Laboratory (University of California, Davis facility located in Byron, California). Chinook salmon will come from one of the state or federal hatcheries (Mokelumne, Nimbus, Orville, or Coleman). Fish will be marked using fluorescent pigments (BIOMETRIX System-1000 Pow'r-jet Powered Injector, Photonic Marking Solution, NewWest Technology, Santa Rosa) approximately 1 week prior to insertions. Each replicate will be assigned a unique tag to differentiate between fish released at different locations and times. Fish will be held in outdoor tanks (1.2 m diameter) at the TAF under ambient conditions. Test fish will be reared in Delta water temperatures for at least 1 week prior to insertion.

#### *Data Analysis/Interpretation*

For all experiments the formulas below will be used to calculate the whole facility efficiency (WFE), secondary louver efficiency (SLE), primary louver efficiency (PLE), and holding tank efficiency (HTE). Since there is no way to capture fish behind the primary louvers it is assumed that all fish released into the primary channel participate in the experiment. Fish passing through the secondary louvers are captured by a sieve net.

The mesh size (2 mm) on this net is small enough to guarantee that fish (70–120 mm FL) will not pass through the net.

TR = Fish released behind trashrack at the front of the facility

HT = Holding Tank

SN = Sieve Net in Secondary Channel behind louvers

rec = recovered fish

rel = released fish at start of experiment

$$\text{HTE} = \frac{\text{HT}_{\text{rec}}}{\text{HT}_{\text{rel}}} \times 100 \quad (\text{this will be assumed } 100\% \text{ once the control test is completed})$$

$$\text{SLE} = \frac{\text{HT}_{\text{rec}}}{(\text{HT}_{\text{rec}} + \text{SN}_{\text{rec}})} \times 100$$

$$\text{WFE} = \frac{\text{HT}_{\text{rec}}}{\text{TR}_{\text{rel}}} \times 100$$

$$\text{WFE} = \frac{\text{PLE} * \text{SLE}}{100}$$

In experiment 2, least squared linear regressions will be used to evaluate if there is a significant positive relationship between secondary louver efficiency and bypass ratio at each of the three secondary channel velocities tested. Bypass ratios above and below 1 will be evaluated separately.

In experiment 3, the whole facility efficiency will be plotted against primary channel BR and primary bypass entrance velocity to look at trends in the data. It is not known if whole facility efficiency will gradually or abruptly rise as BR increases between one and four. In addition it is not known if whole facility efficiency plateaus or peaks as BR increases above one. A step change in efficiency has historically been reported to take place when the BR is near one and this is why facility operating criteria stipulates that the BR must be above one. Based on the results from Sutphin and Bridges (2008), we are expecting to see a large step increase in efficiency once the threshold velocity has been exceeded in the entrance of the primary bypass and this should not happen until the BR is well beyond 1.0. The primary bypass entrance velocity where the step change in whole facility efficiency occurs will be determined with step-wise regression. Least squared liner regression will be used to determine if there is a predictable relationship between whole facility efficiency and primary bypass entrance velocity before and after the threshold value.

In experiment 4, a paired t-test will be used to evaluate if the difference between the two operational methods on facility efficiency is different than zero. This test is appropriate as it will remove most of the environmental and hydraulic variability differences between the pairs. A high degree of variability between the pairs is expected as stage height, light level, turbidity, and debris loads all likely to change between trials.

If these data do not meet the assumptions of the test, a non-parametric alternative will be used (*i.e.*, Wilcoxon paired-sample test).

### Coordination and Collaboration

This experiment will be coordinated with the TFCF staff, the University of California, Davis Delta Smelt Fish Culture and Conservation Lab, and the interagency TTAT group.

### Endangered Species Concerns

Incidental take of winter-run Chinook salmon, steelhead (*Oncorhynchus mykiss*), and delta smelt will be returned to Delta waters as quickly as possible. Totals numbers of each species will be recorded and sent to the reporting agencies. The National Marine Fisheries Service 2009 Biological Opinion allows for take at the TFCF for research purposes.

### Dissemination of Results (Outcomes, Deliverables)

Preliminary results are currently available upon request. Final data collection for year 2010 was postponed until 2011 as the trashrack and primary flowmeter failed during the 2010 season. Final data collection will not be completed until at least June 2011 and a Tracy Series Report will be available for review by December 2011.

### Literature Cited

- Bates, D.W., O. Logan, and E.A. Pesonen. 1960. *Efficiency evaluation, Tracy Fish Collection Facility, Central Valley Project, California*. U.S. Fish and Wildlife Service, Seattle, Washington.
- DWR (Department of Water Resources). 1967a. *Fish collection facilities louver slat spacing tests at Tracy Fish Collecting Facility*.
- DWR (Department of Water Resources). 1967b. *Bypass intake passage spacing tests at the Tracy Fish Collecting Facility*.
- DWR (Department of Water Resources) and California Department of Fish and Game (CDFG). 1973. *Evaluation testing program report for Delta Fish Protective Facility. State water facilities*. California Aqueduct, North San Joaquin Division. Memorandum Report.
- Karp, C., L. Hess and C. Liston. 1995. *Re-evaluation of louver efficiencies for juvenile Chinook salmon and striped bass, 1993*. Tracy Fish Facility Studies, Volume 3, U.S. Bureau of Reclamation, Mid-Pacific Region and Denver Technical Services Center.
- NMFS (National Marine Fishery Service). 2004. *Biological Opinion on the Long-term Central Valley Project and State Water Project Operations Criteria and Plan, October*.

State Water Resources Control Board (SWRCB). 1978. Water Rights Decision D-1485.

Sutphin, Z.A. and B.B. Bridges. 2008. *Increasing juvenile fish salvage efficiency at the Tracy Fish Collection Facility: an analysis of increased bypass ratio during low primary velocities*. Tracy Fish Collection Facility Studies, Volume 35, U.S. Bureau of Reclamation, Mid Pacific Region and Denver Technical Service Center.

USBR (United States Bureau of Reclamation). 1956. *Designers' operating criteria for fish collecting facilities: Delta-Mendota Intake Canal*, Engineering and Research Center, Denver, Colorado.

Zar, J.H. 1999. *Biostatistical Analysis – 4<sup>th</sup> ed.*, Prentice Hall.